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Enhancing the utility of spatial auditory displays for military applications

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University of Louisville

FEBRUARY 2013
Final Report

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Enhancing the utility of spatial auditory displays for military applications

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14. ABSTRACT

This project had the following specific aims: Aim 1: Enhance directional localization accuracy when directional cues are nonindividualized. Aim 2: Enhance distance localization accuracy. Aim 3: Enhance accuracy of perceived trajectories of moving sounds. To accomplish these aims, funding for a state-of-the-art anechoic chamber facility with a robotic loudspeaker positioning system (LPS) was requested. These items of research infrastructure were designed, built, and installed during the funding period, and will serve the University of Louisville and the Commonwealth of Kentucky as valuable assets for facilitating research in the hearing and acoustical sciences for years to come. Due to delays in installation and implementation of these items, and the departure of the project’s original principal investigator (Dr. Frederic Wightman), progress toward the scientific aims of this project, particularly Aims 1 and 3, was less than desirable.

15. SUBJECT TERMS

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FINAL REPORT (06/01/2008– 05/31/2012)

Air Force Office of Science and Research
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REPORT TYPE: Final Report
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AWARD INFORMATION:
GRANT/CONTRACT TITLE: Enhancing the utility of spatial auditory displays for military applications.
GRANT/CONTRACT NUMBER: FA9550-08-1-0234
PRINCIPAL INVESTIGATOR NAME: Pavel Zahorik
PROGRAM MANAGER: Willard Larkin / Susanne Sterbing.

REPORT INFORMATION:
REPORTING PERIOD: 06/01/2008 – 05/31/2012

REPORT ABSTRACT:

This project had the following specific aims:
Aim 1: Enhance directional localization accuracy when directional cues are non-individualized.
Aim 2: Enhance distance localization accuracy.
Aim 3: Enhance accuracy of perceived trajectories of moving sounds.

To accomplish these aims, funding for a state-of-the-art anechoic chamber facility with a robotic loudspeaker positioning system (LPS) was requested. These items of research infrastructure were designed, built, and installed during the funding period, and will serve the University of Louisville and the Commonwealth of Kentucky as valuable assets for facilitating research in the hearing and acoustical sciences for years to come. Due to delays in installation and implementation of these items, and the departure of the project's original principal investigator (Dr. Frederic Wightman), progress toward the scientific aims of this project, particularly Aims 1 and 3, was less than desirable. There was significant progress on Aim 2 of the project, however. The role of visual input on perceived distance in a high-quality virtual auditory display constructed from acoustical measurements from a concert hall on the University of Louisville campus was evaluated. Results from this work suggest that visual input can dramatically improve distance localization accuracy in the auditory display. Results also provide a good picture of typical distance localization inaccuracies, which pave the way for potential compensation strategies in the absence of visual input. This work was reported at the 161st meeting of the Acoustical Society of America, and appears as a refereed proceedings paper. Results from additional and expanded testing will be submitted to a scientific journal shortly.

Word count: 254

ARCHIVAL PUBLICATIONS (PUBLISHED) DURING REPORTING PERIOD:

Anderson, P. W. & Zahorik, P. (2011). Auditory and visual distance estimation. *Proceedings of Meetings on Acoustics, 12*, 050004 [DOI: 10.1121/1.3656353].

EXTENSIONS GRANTED OR MILESTONES SLIPPED, IF ANY:

1-year no-cost extension granted. The revised end date for the project is: 05-31-2012.

INVENTIONS:

None.

SUBCONTRACTS:

None.

FINAL REPORT

Title: (DEPSCoR-08) Enhancing the utility of spatial auditory displays for military applications.
Award Number: FA9550-08-1-0234
PI: Zahorik, Pavel

TOP THREE IMPACTS:

1. Anechoic Chamber. A state-of-the-art anechoic chamber (Eckel Industries, www.eckelusa.com) has been installed in renovated space on the University of Louisville campus. The chamber has useable interior dimensions of approximately 13 x 13 x 13 feet, absorbs all sound produced within the chamber (is anechoic) down to sound frequencies of 190 Hz, and has a background noise level that is at or below the limits of normal human hearing (160 – 1000 Hz). As such, it is an ideal place to conduct high-quality acoustical measurements and contributes significantly to research infrastructure goals (see below). The chamber and associated acoustical testing was completed December, 2009. Stages of chamber design and installation are shown in **Figure 1**.

2. Robotic Speaker Positioning System. A precision robotic system was designed and built by Physical Sciences Lab (www.psl.wisc.edu). This system can quickly and accurately position a loudspeaker at any location on a virtual sphere with radius of approximately 2 meters. The system is to be used to make high-quality measurements of the acoustics of the human head and external ears. Measurements of this type play a key role in spatial audio display technology. Installation of the system was completed in April, 2010, although significant amounts of additional time were required to develop control software for the system. Stages of system design, testing, and installation are shown in **Figure 2**.

3. Potential to improve spatial audio displays. The primary scientific goal of this project was to improve spatial audio display technology. Although spatial audio displays can simulate over headphones what a listener might experience when listening in a real-world situation, including the appropriate spatial position of sounds, certain aspects of such displays have been problematic. For example, sound distance is often not accurately perceived and sound direction may be subject to certain errors that are exacerbated by logistical issues related to measuring the acoustics of the listeners head and external ears, which is required for optimal listening using this technology. Delays in the construction of the anechoic chamber and the implementation of the robotic speaker positioning systems, as well as the abrupt departure of the original PI (Dr. Frederic Wightman) unfortunately resulted in unavoidable delays in the scientific aspects of this project. We have, however, made significant progress on the distance simulation aspects of the project. Details of this work are provided in the Scientific Results section of this report.

ONE GOOD REASON:

Research infrastructure. This project has provided a state-of-the-art acoustical measurement facility and equipment that contributes significantly to the research infrastructure development goals of the University of Louisville and the Commonwealth of Kentucky. This is the only such facility in Kentucky, and one of only a very few in the country. Although the use of this facility for this project is limited to the development of spatial auditory displays, its capabilities are applicable to research and graduate training in a wide variety of scientific disciplines, such as physical acoustics, virtual environment development, mechanical engineering, medical imaging, etc. There is every reason to expect that investigators and their students in these and other disciplines will use the facility, not only in connection with their research, but also for graduate student training. The multidisciplinary appeal of the facility will bring researchers from multiple disciplines into contact with the researchers on this project and thus potentially develop new approaches to the solution of the questions raised by the project. Thus, not is the facility unique, but it brings the potential for multidisciplinary interactions that otherwise would not occur.

SCIENTIFIC RESULTS:
Spatial auditory displays provide a synthesized auditory environment to an operator's ears that accurately simulates a real auditory environment. In other words, although the operator is listening over headphones, what is perceived is an auditory scene consisting of one or more sound sources distributed in three-dimensional externalized space. One important use of a spatial auditory display is to augment a visual display, for example to improve an operator's situational awareness or to guide visual search. Unfortunately, producing a usable spatial auditory display has, in the past, required customization of the display software for each individual operator that includes extensive measurements of the acoustical properties of the operator's ears. This project focuses on 1) ways of avoiding the need for such customization, 2) ways in which a spatial auditory display might be used to enhance auditory distance perception, which is known to be rather poor in real auditory environments, and 3) ways to enhance perception of the trajectories of moving sounds in a spatial auditory display. Taken together, the results provided by the project will point the way to more widespread and effective use of spatial auditory displays in military applications.

The specific aims from the original project were:
Aim 1: Enhance directional localization accuracy when directional cues are non-individualized.
Aim 2: Enhance distance localization accuracy.
Aim 3: Enhance accuracy of perceived trajectories of moving sounds.

Because of delays related to the installation of the anechoic chamber and the robotic loudspeaker positioning system, both of which are critical to the conduct of much of the science related to this project, progress on Aims 1 and 3 has been minimal. Additional and related delays resulted from the abrupt departure of the original PI (Dr. Frederic Wightman). The majority of the systems are now operational, such that acoustical properties of the head and ears may now be measured. Head-related transfer function (HRTF) measurements made using this system are shown in **Figure 3**. The University of Louisville produced a short video describing the project and showing the measurement and experimental procedures. The video is available at:

http://www.youtube.com/watch?v=OIh2rSb0guU (low-resolution)
https://dl.dropbox.com/u/101221112/Research_Minute.mp4 (hi-resolution, 114 MB)

We plan to fine-tune the system by added a system to precisely monitor the head position with the goal of minimizing head movement during the measurement procedures.

Significant progress was made on Aim 2 of the project, however. We have tested the role of visual input in influencing simulated distance in a high-quality virtual auditory display constructed from acoustical measurements in a concert hall on the University of Louisville campus. Results from this work suggest that visual input can dramatically improve distance localization accuracy in the auditory display. Results also provide a good picture of typical distance localization inaccuracies, which pave the way for potential compensation strategies in the absence of visual input. This work was reported at the 161st meeting of the Acoustical Society of America, and appears as a refereed proceedings paper.

Anderson, P. W. & Zahorik, P. (2011). Auditory and visual distance estimation. *Proceedings of Meetings on Acoustics, 12*, 050004 [DOI: 10.1121/1.3656353].

We have now conducted expanded testing on additional participants, as well as a number of additional analyses of the data. These results will be submitted to a scientific journal shortly.

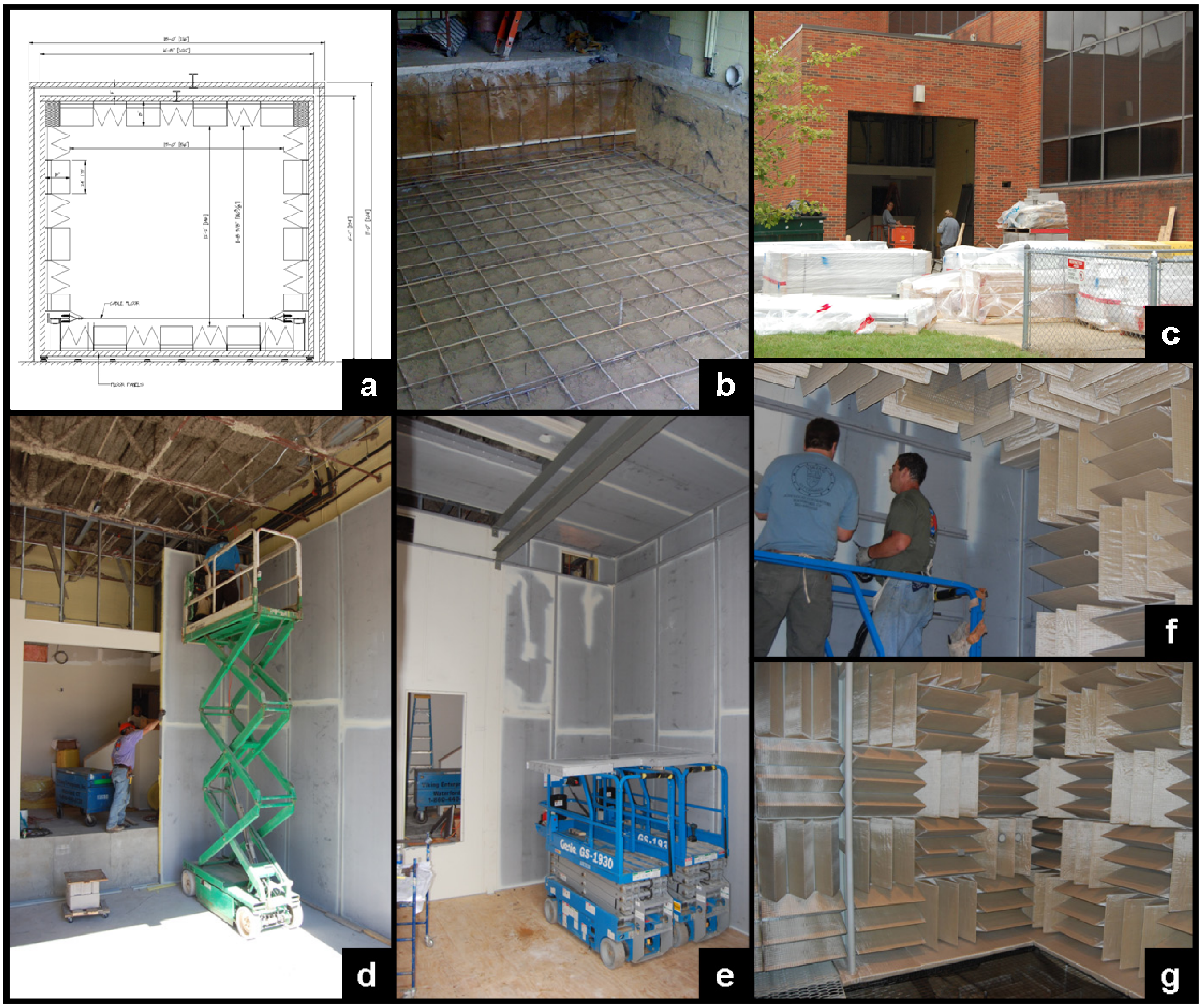

Figure 1. Anechoic chamber design and installation. **a.** Elevation drawing of anechoic chamber. **b.** Foundation preparation at Strickler Hall site on the University of Louisville Campus. **c.** Delivery of chamber materials. **d.** Installation of outer chamber walls. **e.** Installation of inner chamber walls. **f.** Installation of sound absorbing wedges (18-inch depth). Chamber installation was performed by Viking Enterprises, Inc (Waterford, CT). **g.** Completed chamber viewed from inside. Entrance door is visible on the left.

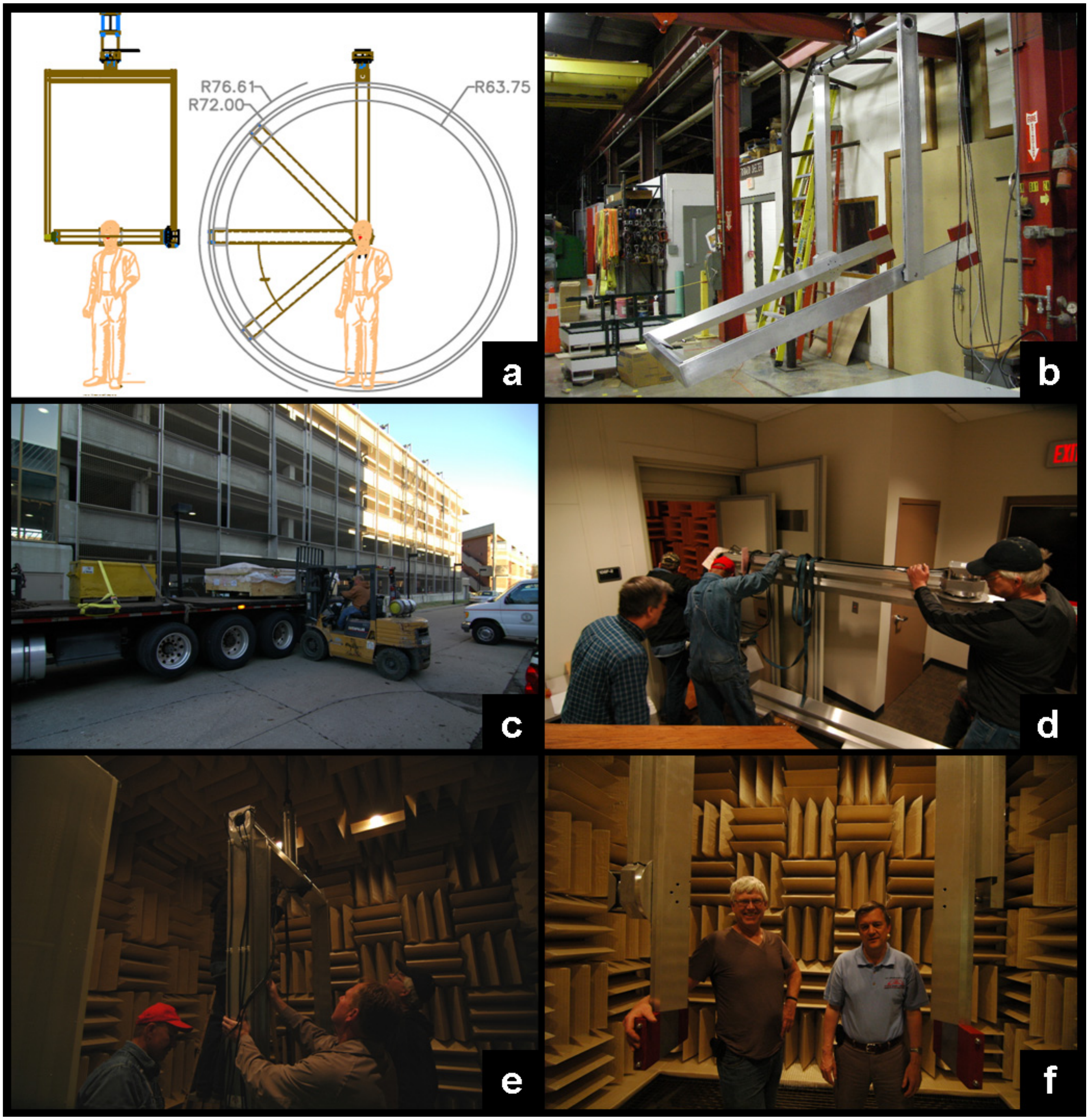

Figure 2. Robotic speaker positioning system design and installation. **a.** System drawings from PSL. **b.** Testing at PSL. **c.** Unloading at Strickler Hall (Padgett, Inc.). **d.** Hand-carry into chamber. **e.** Winch into ceiling motor mount. **f.** Complete. PSL site crew: Darrell Hamilton (left) and Jack Ambuel (right).

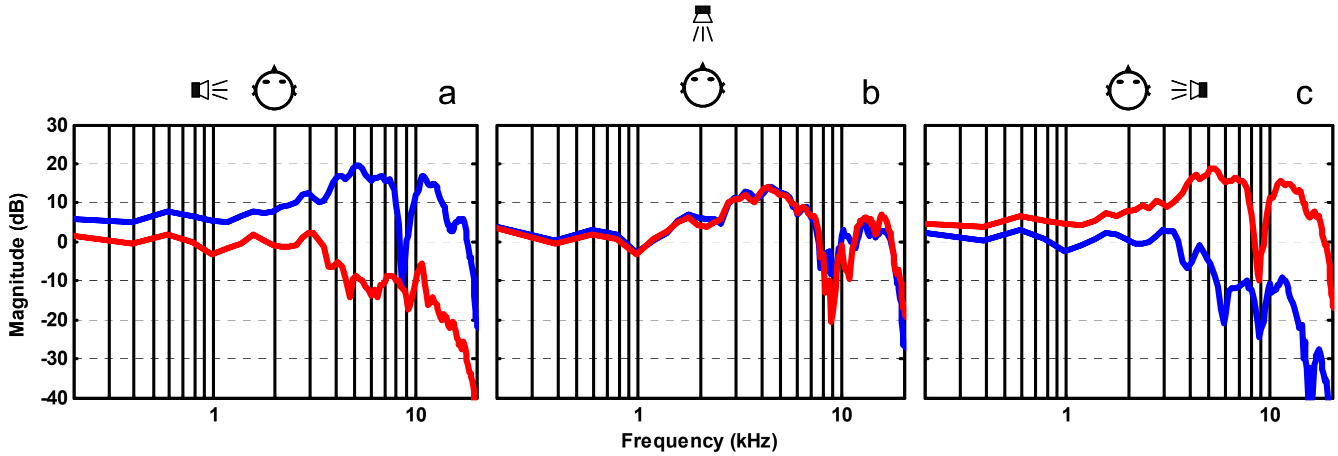

Figure 3. Head-related transfer function measurements (magnitude only) for a single representative listener for three directions on the horizontal plane. Transfer functions for both left (**blue**) and right (**red**) ears are shown.